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Ocean alternative energy
The view from China—'small is beautiful'

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Abstract

The potential harnessing of tidal power has moved, spurred on by the recurring oil crises, from the back- to the front-burner, again. Concerns over global warming seem to point to an absolute and urgent necessity to limit the burning of fossil fuels. China has huge reserves of coal and they are used on a very large scale to provide heating and energy. The replacement of that source of power is not to be expected in the near future, but China has been looking for several decades at alternative sources. The ocean is one of them. The paper does not aim at comprehensiveness but attempts to provide a review of China's efforts in that domain based on several sources and trips to China and Japan. © 2001 Elsevier Science Ltd. All rights reserved.

1. Introduction

Concerns about periodically rising oil and gas prices and steadily increasing carbon dioxide emissions have led to a re-examination of the matter of finding new alternative energy sources or reconsidering those already known. Perhaps this is the more so since the gap between the cost of generation using new approaches and that of traditional plants has narrowed. The promise of tidal power for the 21st century has been underscored repeatedly in the immediate past, witness the Royal Society (UK) Parsons Memorial Lectures in both 1997 and 1999 [1,2].

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The French [3,4], Russians [5] and Canadians [6] have discussed and re-analyzed the single tidal power plant each of these countries has constructed. Whereas the Koreans still think in terms of large tidal power stations [7], the Chinese have been concentrating on small facilities that address themselves to local, at best regional, needs. The idea is not new [8–11] but China has put it into practice. Probably for financial or practical reasons, China has tried to limit construction costs by utilizing existing dams rather than constructing new barrages.

2. The Far East panorama

There is little doubt that in the Far East the Japanese are the leading researchers in the harnessing of energy from the ocean, predominating in wave energy development [10] (pp. 119–122, 133–139, 165–168, 174). They are a little less active in other fields (e.g. tidal power near Kyusyu on Ariake Bay) though their work is far from insignificant, for instance in OTEC [10] (pp. 201–205), [12]. The study on the Ariake tidal power station was concluded prematurely since the project was not economically viable. Use of the Straflo turbine would have cut costs which were at least double those required for other means of power generation. Multiple uses of the construction—such as the four-lane highway constructed on the top of the barrage at the Rance River station in France—may also have helped the financial situation.

Considerable interest has also been shown in the utilization of tidal power in Korea, where tidal currents in the narrow Korea Strait have been investigated. Korea is engaged in wave-energy trapping and had considered tidal power as an additional source of energy as early as 1974. A feasibility study was carried out in 1975 at Cheonsu Bay, then at Garolim Bay in 1976, 1980 and 1981, and at Incheon Bay in 1978. A decision was taken in 1983 to construct a small pilot tidal power plant [13]. However, a damper on the project came from geological studies which warned about the size of the silting process [14].

The matter progressed to the point of signing a contract with Sogreah, a firm based in Grenoble, one of the major companies involved in the construction of the Rance River plant, now in its 30th year of operation [3] near St Malo in France [15], also involved in preliminary studies in Argentina (Gulf of San Jose) and in Australia [9]. Although neither financial nor physical problems stood in the way of bringing in the first bulldozer, politics derailed the project. At the time, relations between South Korea (where the plant was to be built) and North Korea were not good. Overarching economic advantages led France to establish diplomatic relations with North Korea and South Korea canceled the agreement. According to the Korean Tidal Power Project's timetable, operation of the power plant was to start in 1986. As the French would say: *on en est loin*.

Nevertheless, active interest for tidal power [7,13,16,30] in Korea remains, although progress has certainly been hindered by a less than favorable economic climate.

3. China's endeavors and achievements

In discussions on the use of salinity differential to produce electricity, China stressed its gigantic 'resource of the Yangtze River' (2.2×10^4 m^3/s flow rate, 24 atm of osmotic pressure and 5.2×10^{10} W). It mentioned its potentially exploitable tidal energy of 90 billion kW/h or the 7000 kW that could be extracted from the Chientang River. Taiwan, in the wake of the oil crises of the 70s, embarked on plans to build OTEC[1] facilities at various sites, the most likely being Ho-ping, but again the capital investment required produced a braking effect. China looked at wave energy conversion as early as 1968 and built wave-powered ship models the following year. In the same year Chinese engineers constructed a wave-powered turbine and an improved one 10 years later, obviously not discouraged by an unsuccessful test on the East China Sea in 1972. A device for navigation lights, parallel to a Japanese one, was developed using wave energy. Work has now been systematically pursued for 20 years and tests conducted among others in 1984 and 1985. During the 90s a small scale wave-power generating station was constructed at the mouth of the Pearl River. Official pronouncements are that "the Government of the People's Republic of China intends that numerous 'wave stations' will provide power, particularly in island situations, as have the tidal power stations which have been running in China for some time".

4. Tidal energy

But it is in the area of harnessing tidal energy that the most concrete and most numerous (claims vary from 105 to 128 plants) achievements have been realized. An All Chinese Conference on Tidal Power was held in Shanghai in 1959 [17], although the potential and future of tidal power for the country had been discussed even earlier [18,19]. In the 80s three gulfs—Fuchin Wan, Shinhwwang Wan and Sanmen Wan—with a capacity exceeding 1000 MW were under study. At the International Ocean Development Conference in Tokyo in September 1978, Chinese researchers announced the intended construction of 80–90 plants whose joint capacity would represent over 7000 kW.

One would be less than candid not to recognize that information on energy related matters is difficult to gather even when in China. Nevertheless, claims that a large number of tidal power plants have been constructed and are successfully in operation are probably correct. Furthermore, plans to undertake new constructions have been divulged, even though in publications that are rather obscure, or difficult for westerners to access [20]. This is somewhat surprising and disappointing as China is the seat of UNESCO/UNDP's Training Center on Small Hydro Power, located at Hangzhou; the Center publishes a newsletter which reports details on small plants

[1] Ocean Thermal Energy Conversion.

on a regular basis, but has shown over the years a definite lack of information on electricity development, particularly ocean-related.

The tide mill is the forerunner of the contemporary tidal power plant [29]. Yet, the author was unable to discover whether tide mills have ever operated on Korean coast—a region where waves of large amplitude create a preferred site for tidal power plants. Similarly there is no record of tide mills having been built in northeast China, However, information gathered at the Sixth International Congress on the History of Oceanography (Qingdao, China, August 1998) places numerous such mills on the estuaries and coasts of southeast China.

It seems there has been a lack of thorough environmental and geological studies at several sites. It is this author's impression that not much emphasis has been placed on environmental impacts when major projects were implemented (e.g. a new nuclear power plant built off-shore by the French does not seem to have taken account of pollution by cooling water discharges). Lack of a thorough geological assessment of a site led to disabling of some plants. Chinese engineers acknowledged[2] a problem with siltation, the extent of which is difficult to assess, but word has it that some tidal power plants were put out of commission because of the accumulation of sediments. In all fairness it must be mentioned that an environmental impact statement was issued at the time of construction of the Baishakou station [21]. Records exist, transmitted orally in Beijing to the author, that some plants were 'temporarily' abandoned. In plain language they have been put out of commission and no definite plan to restart them exists at the time of writing. In practical terms, lack of maintenance of the retaining pool(s) and proper operation, rather than technical difficulties, are the likely culprits.

5. A view of some major plants

The total capacity of Chinese plants reached 583 kW in 1958, with 40 small plants generating power. Current capacity has been reported at 7638 kW. Few projects advocate two or more basins schemes; this makes the Taliang station on the Shunte River the more remarkable. This multiple-basin complex is the largest single plant in China with a total capacity of 304 kW; three turbines placed between the upper and lower pools have a 144 kW capacity and five others placed between the lower pool and the Shunte River have 160 kW capacity. Assuming that 'date' records are correct China, rather than France, was the first country to build a tidal power plant. Such a plant with a single generating set was put into service in 1959, with a capacity of 40 kW in Zhejiang Province. By 1970 six tidal power plants with 19 sets of turbines totaling over 100 kW were operational in Zhejiang, Jiangsu and Shandong provinces. The somewhat better known central of Gau Tung is among these plants.

Somewhat surprisingly some heads of Chinese plants are quite low as they range from 3.49 to 7.8 m (11.45 to 25.6 ft.); the capacities of units vary from a low 75

[2] Communication from Zhu Xiaochang, director of the Training Center on Small Hydro Power.

kW to 160 kW. Still in Zhejiang province (Wen Lin region), the Jian Xia plant was constructed in 1980 and became operational (with a single generator set) utilizing a 8.39 m head (27.53 ft.) during the summer of the same year. Today, the station includes six sets of turbines of 500 kW each. The Jian Xia and Liu He Kuo plants are double-effect[3] centrals; all other plants are single-effect[4] schemes.

Ch'iu described the Shamen plant, which was already operational in 1958 [20]. Hiao described the turbo-pumps used in the stations [27]. The overall role of small hydropower for the electricity planning of China was analyzed in 1979 [22], and also in 1980 by Mao and Deng [26], and also elicited a study by the (US) Central Intelligence Agency. Zhikui Zhu presented in 1992 an analysis of data pertaining to the Baishakou tidal power station [21]. It describes measures taken to control sedimentation in the tallway channel and the reservoir area. Comprehensive management is outlined, including mechanical sand-proofing methods and environmental protection.

The interest of Chinese researchers in tidal power plants has not waned, nor become somnolent, as in Europe and the United States, due undoubtedly to the abundance and low cost of fossil fuel. An exploratory study and modeling were recently conducted [23].

A review article on Chinese activity in tidal power utilization covering the 1950–1990 period was published in the somewhat (to westerners) unfamiliar *Collection of Oceanographic Works*. The information contradicts to some degree other releases which mention about 100 small tidal power plants. Guixiang Li mentions eight small power stations and discusses their tangible economic and social benefits [28]. He further discloses that "many more" small and medium sized plants, even one or two large plants "will be built by the year 2000" along the coasts of China's mainland and the coastal islands. The publication is rather difficult to obtain, except perhaps via the University of Karlsruhe (Germany). At the time of writing no further information has been provided concerning any plants planned for the year 2000.

6. Closing remarks

The Chinese have chosen the motto 'small is beautiful' either out of financial necessity or, more probably, because a major plant would provide power to a large region, without solving the plight of many small areas for the electrical energy needed to support an embryonic industry or to save it from abandon due to the lack of price competitiveness. If construction in the dry is doubtful, it is nevertheless probable that they avoided the expense of putting up cofferdams. In most plants, electricity generation is probably limited to the flood current; however, ebb generation is or has been considered [24] and so has flood-and-ebb generation, for instance

[3] Generating power at both flood and ebb tide.

[4] Generating power only at ebb tide.

at the Jiangxca plant [25]. The least that can be said is that in China ‘they’ do, in our climes thus far ‘they’ talk.

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